MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2021/2022

ETN4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS

(All Sections/Groups)

10 AUGUST 2022
9.00 a.m. - 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This question paper consists of **FOUR** printed pages (including the cover page) with **FOUR** questions.
2. Answer **ALL** questions.
3. Write your answers in the Answer Booklet.

Question 1 (25 marks)

(a) Name and describe **TWO (2)** types of optical fibers that can be classified based on its mode of propagation. Your answer must include **TWO (2)** characteristics of each fiber type. [6 marks]

(b) An optical fiber with a core diameter of 60 μm, a refractive index profile of 2, and a numerical aperture of 0.22 is operating at the wavelength 1550 nm. Estimate the number of guided modes in this fiber. Based on this fiber's parameters including its refractive index profile, name this fiber type. [4+1 marks]

(c) An optical fiber has an attenuation of 0.30 dB/km at the operating wavelength of 1310 nm and an attenuation of 0.16 dB/km at the operating wavelength of 1550 nm. Which operating wavelength will give a better performance in a fiber optical link with a length of 80 km? Justify your answer with suitable calculations. [5 marks]

(d) Why do intrinsic and extrinsic absorption occur in a silica glass fiber? Give **ONE (1)** reason for each type of absorption. [4 marks]

(e) Does intersymbol interference (ISI) limits the information carrying capacity of an optical fiber? Justify your answer with a suitable explanation of how ISI occurs. [1+4 marks]

Question 2 (25 marks)

(a) Compare **TWO (2)** differences between an edge-emitting laser and a surface-emitting laser. [4 marks]

(b) What can potentially damage or affect the performance a laser diode? Give **TWO (2)** examples. [4 marks]

(c) Describe **TWO (2)** basic characteristics of a light emitting diode (LED) that makes it suitable to be used in short haul applications compared to laser diodes. [4 marks]

(d) Which type of fiber amplifier is commonly used in a wavelength division multiplexing (WDM) fiber communication system? Give **ONE (1)** reason to justify your answer. [1+2 marks]

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Question 2 (Continued...)

(e) Avalanche photodiodes are widely used in optical communications.

(i) Describe the main advantage of an avalanche photodiode when compared to other types of photodiodes. Your answer must include the description of the impact ionization process as well. [6 marks]

(ii) Describe **TWO (2)** disadvantages of an avalanche photodiode [4 marks]

Question 3 (25 marks)

(a) With suitable equations, define shot noise and thermal noise. Your answer must include definitions of the noise and all the variables in the equations. [6 marks]

(b) What causes avalanche noise in an avalanche photodiode? Your answer must include a description of how avalanche noise occurs. [3 marks]

(c) At a wavelength of 1300 nm, the quantum efficiency of an InGaAs *pin* photodiode is 90% with a dark current of 5 nA and a load resistance of 1000 Ω. The incident optical power at 1300 nm is 1 μW, and the receiver bandwidth is 15 MHz. Determine:

(i) The primary photocurrent generated. [3 marks]

(ii) The rms shot noise current generated. [3 marks]

(iii) The rms dark current noise generated. [3 marks]

(iv) The rms thermal noise in the load resistor at a temperature of 20°C. [3 marks]

(v) Based on your answer in Question 3 (c)(ii)-(iv), which noise current contributes the highest noise in the receiver? [1 mark]

(vi) The signal-to-noise ratio (SNR) in dB when the primary photocurrent is the signal. [3 marks]

Question 4 (25 marks)

(a) In an optical communication network named Network A, the optical source has an input power of 1 mW and the optical detector has a receiver sensitivity of -40 dBm. The optical fiber used has an attenuation of 0.32 dB/km at the wavelength of 1310 nm. A 6 dB system margin is required in the network. There is also 3 connectors being used where each connector has a loss of 0.5 dB/connector. Determine the maximum possible transmission distance for Network A. [5 marks]

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Question 4 (Continued..)

(b) The optical source in Network A in Question 4 (a) has been changed to a source with an input power of -10 dBm and the detector has been changed to a detector with a receiver sensitivity of -30 dBm. All other parameters remain the same as per Question 4 (a). Will the maximum possible transmission distance for Network A increase or decrease? Justify your answer by showing relevant calculations. [5 marks]

(c) In Question 4 (a), can the maximum possible transmission distance for Network A be increased by using a different operating wavelength? Justify your answer with suitable examples and calculations. [5 marks]

(d) An additional 5 connectors with a loss of 0.2 dB per connector had been added to Network A in Question 4 (a). To ensure the same transmission distance as per the answer in Question 4 (a), what happens to the system margin? Justify your answer by showing relevant calculations. [5 marks]

(e) In designing an optical communication sytem, is power budget analysis the same as the rise time budget analysis? Justify your answer. [1+4 marks]

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	2.998×10^{8} m/s
Electron charge	e	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

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